

WHAT IS CLAIMED IS:

1. An electromagnetic actuator comprising:  
a core with a coil wound around;  
a stator magnetically coupled at both ends of said  
5 core;

a movable element that can be displaced relative  
to said stator; and

a supporting means for supporting said movable  
element,

10 wherein said stator and said movable element each  
have a projection and a depression perpendicular to  
their respective displacement directions and are placed  
in such a way that the projection and depression of  
said stator engage with the projection and depression  
15 of said movable element.

2. The electromagnetic actuator according to  
claim 1, wherein said supporting means and said stator  
are fixed onto a substrate.

20 3. The electromagnetic actuator according to  
claim 1, wherein said supporting means, said stator and  
said movable element are made of a same material.

25 4. The electromagnetic actuator according to  
claim 1, wherein said supporting means is a parallel  
hinge spring made up of a plurality of flat springs

combined in parallel, and the projections and  
depressions of said stator and the projections and  
depressions of said movable element are formed like  
comb-teeth parallel to the direction of movement of  
5 said parallel hinge spring.

5. The electromagnetic actuator according to  
claim 1, wherein said supporting means is a concentric  
hinge spring combining a plurality of flat springs in a  
10 concentric radial form, and the projections and  
depressions of said stator and the projections and  
depressions of said movable element are formed in a  
concentric form around the center of rotation of said  
concentric hinge spring.

15 6. An optical scanner, comprising:  
a movable mirror; and  
the electromagnetic actuator according to claim 1  
mechanically connected with said movable mirror.

20 7. A method of manufacturing the electromagnetic  
actuator according to claim 1, wherein a process of  
manufacturing said stator, said movable element and  
said supporting means comprises:

25 a step of forming a sacrificial layer on a  
substrate;

a step of forming an electrode layer on said

substrate and said sacrificial layer;

a step of forming an insulated female mold layer on said electrode layer;

a step of electroplating a magnetic layer in an opening of said insulated female mold layer on said electrode layer; and

a step of removing said insulated female mold layer and said sacrificial layer.

8. The method of manufacturing the electromagnetic actuator according to claim 7, wherein said insulated female mold layer is comprised of photoresist.

9. The method of manufacturing the electromagnetic actuator according to claim 1, wherein a process of manufacturing said core and said coil comprise:

a step of forming coil lower wiring on the substrate;

a step of forming a first insulating layer on said coil lower wiring;

a step of forming an electrode layer on said first insulating layer;

a step of forming an insulated female mold layer on said electrode layer;

a step of electroplating a magnetic layer in the

opening of said insulated female mold layer on said electrode layer;

a step of forming a second insulating layer on said magnetic layer; and

5 a step of forming coil upper wiring on said second insulating layer.

10. The method of manufacturing the electromagnetic actuator according to claim 9, wherein  
10 said insulated female mold layer is comprised of photoresist.

11. An optical scanner, comprising:

a movable mirror; and

15 the electromagnetic actuator according to claim 2 mechanically connected with said movable mirror.

12. A method of manufacturing the electromagnetic actuator according to claim 2, wherein a process of  
20 manufacturing said stator, said movable element and said supporting means comprises:

a step of forming a sacrificial layer on a substrate;

25 a step of forming an electrode layer on said substrate and said sacrificial layer;

a step of forming an insulated female mold layer on said electrode layer;

a step of electroplating a magnetic layer in an opening of said insulated female mold layer on said electrode layer; and

5 a step of removing said insulated female mold layer and said sacrificial layer.

13. The method of manufacturing the electromagnetic actuator according to claim 12, wherein said insulated female mold layer is comprised of  
10 photoresist.

14. The method of manufacturing the electromagnetic actuator according to claim 2, wherein a process of manufacturing said core and said coil  
15 comprise:

a step of forming coil lower wiring on the substrate;

a step of forming a first insulating layer on said coil lower wiring;

20 a step of forming an electrode layer on said first insulating layer;

a step of forming an insulated female mold layer on said electrode layer;

25 a step of electroplating a magnetic layer in the opening of said insulated female mold layer on said electrode layer;

a step of forming a second insulating layer on

said magnetic layer; and

a step of forming coil upper wiring on said second insulating layer.

5           15. The method of manufacturing the electromagnetic actuator according to claim 14, wherein said insulated female mold layer is comprised of photoresist.

10           16. An optical scanner, comprising:  
a movable mirror; and  
the electromagnetic actuator according to claim 3 mechanically connected with said movable mirror.

15           17. A method of manufacturing the electromagnetic actuator according to claim 3, wherein a process of manufacturing said stator, said movable element and said supporting means comprises:

20           a step of forming a sacrificial layer on a substrate;

a step of forming an electrode layer on said substrate and said sacrificial layer;

a step of forming an insulated female mold layer on said electrode layer;

25           a step of electroplating a magnetic layer in an opening of said insulated female mold layer on said electrode layer; and

a step of removing said insulated female mold layer and said sacrificial layer.

18. The method of manufacturing the  
5 electromagnetic actuator according to claim 17, wherein said insulated female mold layer is comprised of photoresist.

19. The method of manufacturing the  
10 electromagnetic actuator according to claim 3, wherein a process of manufacturing said core and said coil comprise:

a step of forming coil lower wiring on the substrate;

15 a step of forming a first insulating layer on said coil lower wiring;

a step of forming an electrode layer on said first insulating layer;

20 a step of forming an insulated female mold layer on said electrode layer;

a step of electroplating a magnetic layer in the opening of said insulated female mold layer on said electrode layer;

25 a step of forming a second insulating layer on said magnetic layer; and

a step of forming coil upper wiring on said second insulating layer.

20. The method of manufacturing the electromagnetic actuator according to claim 19, wherein said insulated female mold layer is comprised of photoresist.

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21. An optical scanner, comprising:  
a movable mirror; and  
the electromagnetic actuator according to claim 4 mechanically connected with said movable mirror.

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22. A method of manufacturing the electromagnetic actuator according to claim 4, wherein a process of manufacturing said stator, said movable element and said supporting means comprises:

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a step of forming a sacrificial layer on a substrate;

a step of forming an electrode layer on said substrate and said sacrificial layer;

20

a step of forming an insulated female mold layer on said electrode layer;

a step of electroplating a magnetic layer in an opening of said insulated female mold layer on said electrode layer; and

25

a step of removing said insulated female mold layer and said sacrificial layer.

23. The method of manufacturing the



electromagnetic actuator according to claim 22, wherein said insulated female mold layer is comprised of photoresist.

5           24. The method of manufacturing the electromagnetic actuator according to claim 4, wherein a process of manufacturing said core and said coil comprise:

10               a step of forming coil lower wiring on the substrate;

              a step of forming a first insulating layer on said coil lower wiring;

              a step of forming an electrode layer on said first insulating layer;

15               a step of forming an insulated female mold layer on said electrode layer;

              a step of electroplating a magnetic layer in the opening of said insulated female mold layer on said electrode layer;

20               a step of forming a second insulating layer on said magnetic layer; and

              a step of forming coil upper wiring on said second insulating layer.

25           25. The method of manufacturing the electromagnetic actuator according to claim 24, wherein said insulated female mold layer is comprised of

photoresist.

26. An optical scanner, comprising:  
a movable mirror; and  
the electromagnetic actuator according to claim 5  
mechanically connected with said movable mirror.

27. A method of manufacturing the electromagnetic  
actuator according to claim 5, wherein a process of  
manufacturing said stator, said movable element and  
said supporting means comprises:

a step of forming a sacrificial layer on a  
substrate;

a step of forming an electrode layer on said  
substrate and said sacrificial layer;

a step of forming an insulated female mold layer  
on said electrode layer;

a step of electroplating a magnetic layer in an  
opening of said insulated female mold layer on said  
electrode layer; and

a step of removing said insulated female mold  
layer and said sacrificial layer.

28. The method of manufacturing the  
electromagnetic actuator according to claim 27, wherein  
said insulated female mold layer is comprised of  
photoresist.

29. The method of manufacturing the electromagnetic actuator according to claim 5, wherein a process of manufacturing said core and said coil comprise:

5           a step of forming coil lower wiring on the substrate;

          a step of forming a first insulating layer on said coil lower wiring;

10           a step of forming an electrode layer on said first insulating layer;

          a step of forming an insulated female mold layer on said electrode layer;

15           a step of electroplating a magnetic layer in the opening of said insulated female mold layer on said electrode layer;

          a step of forming a second insulating layer on said magnetic layer; and

          a step of forming coil upper wiring on said second insulating layer.

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30. The method of manufacturing the electromagnetic actuator according to claim 29, wherein said insulated female mold layer is comprised of photoresist.